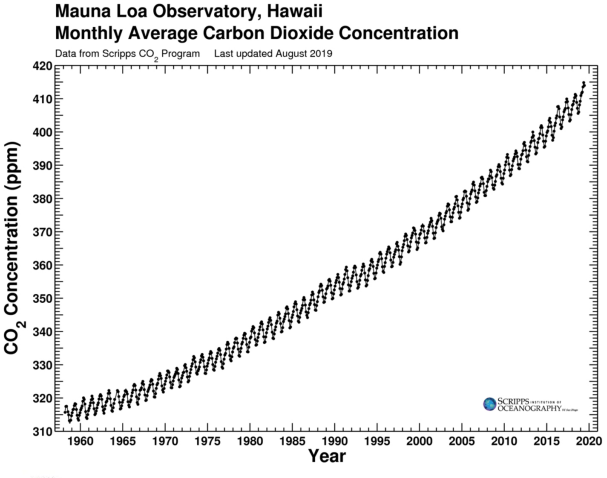
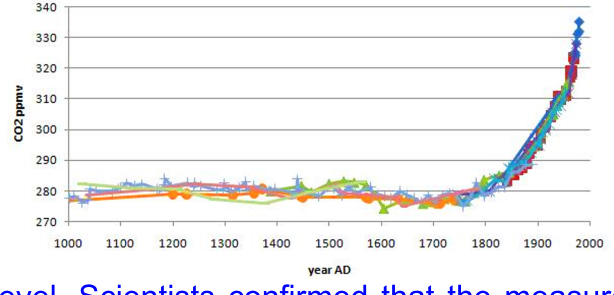
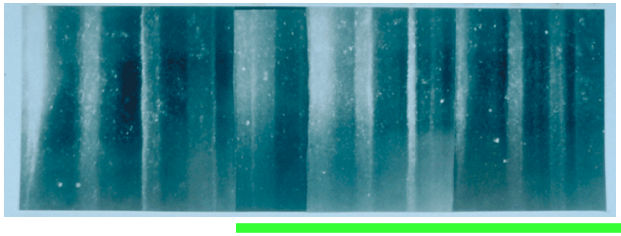

Mauna Loa Observatory, Hawaii
Monthly Average Carbon Dioxide Concentration
Data from Scripps CO2 Program Last updated August 2019
CO2 Concentration (ppm)
Year
SCRIPPS OCEANOGRAPHY



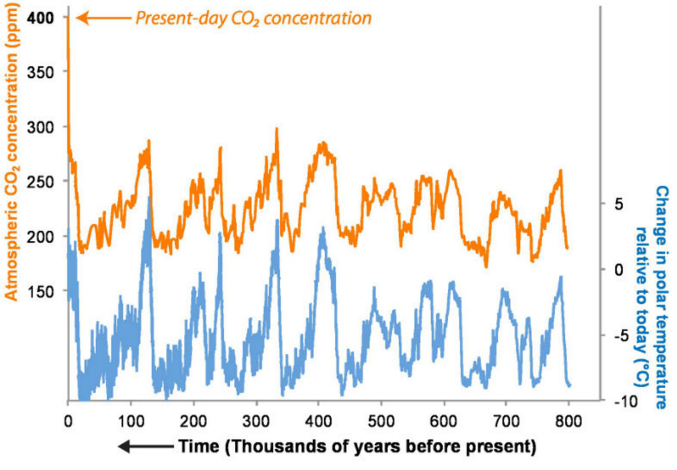
Nearly eighty thousand years ago, there were a handful of humans and all of them were in the grasslands of Africa. Today, the earth is home to more than seven billion people. The growth has been particularly fast in the last couple of centuries. The population was nearly one billion even in the year 1800. Since then the population has increased sevenfold. But the total energy consumed by humans has increased by a factor of thirty. Coal, petroleum products and natural gas have provided most of this energy. This in turn is increasing the concentration of carbon dioxide gas in the atmosphere. On an average, the concentration of carbon dioxide was below 0.028% in 1800 but it was 0.0315% in 1960. By the year 2019 it has increased to 0.041%. {Pictures left top and bottom} The recent values are the results from the Mauna Loa laboratory. This is located on an island in the center of the Pacific ocean at an altitude of more than 3000 m above sea level. Scientists confirmed that the measurements made there are a good average value for the entire atmosphere. Measurements have been continuously made for over 70 years and the average value has increased by about 25%. Every year, the value decreases by about 1.5% between October to April and increases again in the next six months. This is

caused by the land area being larger in the northern hemisphere of the earth and sea area being larger in the southern hemisphere. So the total growth of trees during April in the southern hemisphere is lower than the total growth of trees in October in the northern hemisphere. The carbon dioxide consumed by tree growth is more in October. This causes the change in carbon dioxide concentration during the year. Many processes in nature change the carbon dioxide concentration. Only some of them involve living beings. Trees absorb carbon dioxide during the day. They release a smaller quantity during the night. When sea temperature increases, carbon dioxide is released into the atmosphere. The Mauna Loa measurements are the average of such natural processes and human actions.



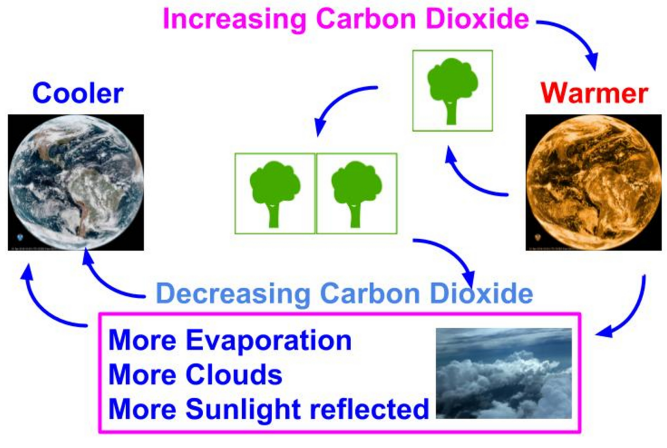
How can we know the concentration of carbon dioxide in the atmosphere before 1800 was lower than 0.028%? Near the poles, snow falls in winter. Not all of it melts during summer. This snow has accumulated for thousands of years. The deeper snow has frozen into ice because of the weight of more recent snow on top. Using special machines, long cylinders of ice are extracted. {Pictures left} The yearly snowfall forms a clearly visible layer. The air at the time of snowfall is trapped in these layers as very small bubbles. These layers are carefully melted in the laboratory and the concentration of carbon dioxide is measured.

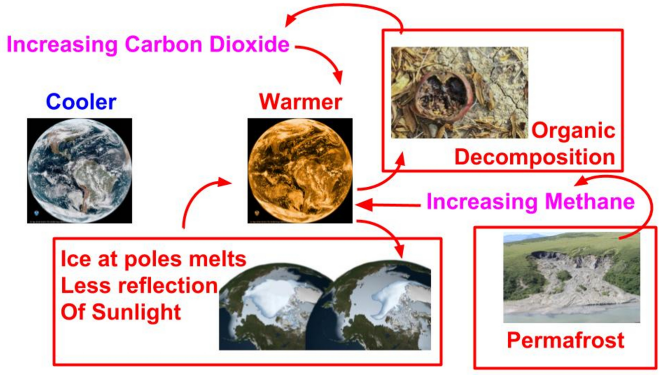
When large asteroids fall on earth or when volcanoes explode, the atmosphere is filled with soot. This forms dark layers in the ice cylinder. These help in identifying the years from the history of volcanic eruptions. The carbon dioxide concentration is thus directly measured. The average temperature is an estimate from the ratio of oxygen isotope concentrations. {Picture right}



When the measurements from Mauna Loa are compared with the measurements from the ice cylinders, it becomes clear that the carbon dioxide concentration increased rapidly after 1700, coinciding with the industrial revolution. From ice core data one can easily see that as the concentration of carbon dioxide in the atmosphere increases from 0.015% to 0.03%, the average temperature increases from -10C to 5C. Nowadays, only the areas near the poles are covered with ice throughout the year. When the carbon dioxide concentration is very low, this area expands towards the equator. Because more water has become ice, the sea level decreases. These are called ice ages. Since the present concentration of carbon dioxide is more than at any time in the past, scientists expect that the average temperature will increase, and that the sea level will rise, submerging some of the islands and coastal areas.

The ice core data is however very complex And the complexity is again due to positive and negative feedback loops. If the average temperature increases, trees grow faster. They

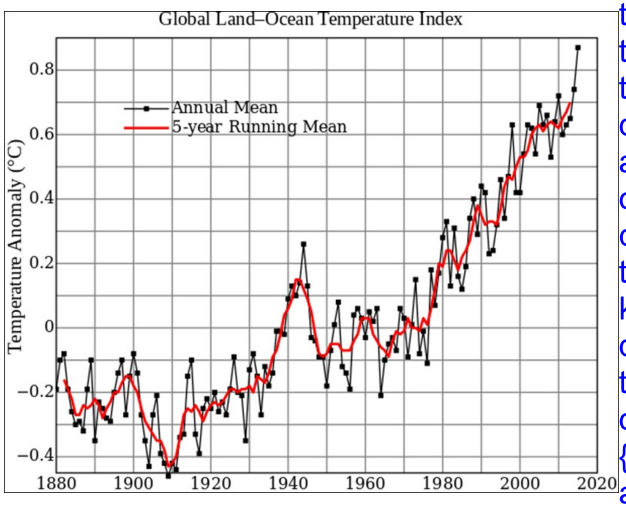




consume more carbon dioxide. This could decrease the carbon dioxide concentration and hence the average temperature. This is the reason, growing of trees is a big part of the efforts for protecting the environment. When the average temperature increases, more water would evaporate, more clouds could form, reflecting more sunlight into space and this would help decrease the temperature. These are both examples of negative feedback. {Picture left top} But when temperature increases and the ice cover near the poles decreases, less of the sunlight is reflected. This further increases the temperature. Similarly, if the permafrost near the poles melts and releases trapped methane, temperature will increase further. When the average temperature increases, decomposition of dead animals and plants {Picture left bottom} increases the carbon dioxide concentration and thus increases the temperature and decomposition. These are all good examples of positive feedback. Some of the feedback processes are even more complex. For example, if the increase

in temperature disturbs ocean currents such as the gulf stream, there could be severe disturbance of the environment.

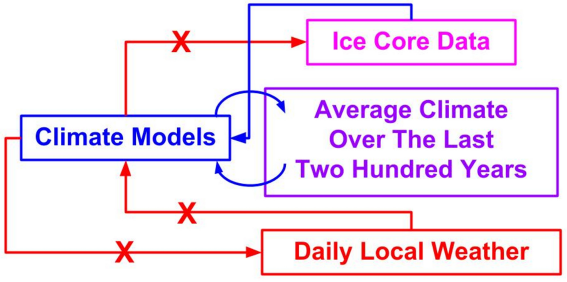
The molecules in living organisms always obey laws of chemistry. But because of the complexity due to feedback loops, comparing identical groups is the only method available for the scientific investigation. There is complexity due to feedback loops even in the environment. But there is only one environment. We cannot compare groups. Moreover, any measurement has to be made at one location and at one time. This is true of carbon dioxide concentration, temperature or anything else. For example, temperature at a given location and time changes with the local time. Even the maximum and the minimum temperatures change from day to day. They change if the day is cloudy. They change if there is rain at that location. They change with the seasons. When there is a volcanic eruption they change for the next few months. So what does an increase in the average temperature actually mean? We can calculate the average of the maxim and minimum temperature and consider that as the representative average temperature of that place and time. We can keep averaging such averages measured at different places and thus get some average temperature of the earth. The averages taken over one year and over five years do not agree {Picture left} completely. However, all these averages do show a consistent 1°C increase



over the last 125 years. Comparing with ice core data and concluding that this increase is due to the increased carbon dioxide concentration is perfectly reasonable.

Scientists have developed mathematical relationships for each of the known feedback loops in the environment. These have all been combined into a huge computer program. Sensational reports claim that by the end of the century, sea level will rise by "XX" meters and that "YY" million square kilometers of land will be submerged. Or that "zz" million hectares of cultivated land will become a desert. Or that "PP" super cyclones can be expected. Or that "RR" species of living organisms will become extinct. These conclusions are all based on computer models.

But the foundations of the computer model are weak. None of the mathematics used goes against known physics or chemistry. But, because there is only one environment, there are no ways of independently verifying them. More importantly, all the measurements are averages. The model neither uses the daily local climate data nor can it predict the local weather over the next few days {Picture below}. While the model takes inputs from the ice core data, it cannot predict the complex changes seen in ice core data. Do the averages have great strength? For example is it sufficient if the average of the maximum and the minimum temperatures does not change much? Even if the maximum and minimum remain the same, if the maximum temperature lasts a bit longer or shorter, the effect on living beings would be different. Is 2 mm of rain per day for ten days equal to 2 cm of rain on one of the days? But the averages are the



same? The basic foundations of the computer model are shaky. The only firm conclusion possible is that when a large number of humans are using more and more energy from fossil fuels for a comfortable life, there are likely to be major changes in the environment. The details are unreliable. We can guess some of those conclusions. We cannot quantify them.

The plans and programs for reversing the prevention of global warming, offered by experts and scientists to the governments are even less reliable. These programs seek to tax some industries and give subsidies to some others. They demand other government actions. It is difficult to believe the calculations which suggest these remedial measures. Looking at the complexity of the ice core data, one cannot be certain that an abrupt end to use of all fossil fuels would certainly stop global warming or sea level changes in the immediate future.

The limitations of averages encountered with medical and environmental science become extremely severe in economics and other social sciences. We will next consider these issues of knowing the strength and hence utility of measurements.